Advancements in Manikin Technology: Enhancing Realism and Effectiveness in Nursing Education

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***Abstract*–** *With the modern advancement of technology, use of manikins plays a major role in nursing education. Manikins are anatomically accurate simulators that replicate human physiology and provide a realistic representation of patients in various clinical scenarios. The historical development of manikins originated from 18th century by introducing the anatomical models in nursing education. The simulation-based training was evolved the manikins as rudimentary mechanical simulators enabled the learners to practice basic skills, such as bandaging or intramuscular injections, on realistic models. With the technological progression, different types of manikins have been developed based on level of fidelity, functionalities incorporating realistic physiological responses and educational outcomes for nursing students to develop a wide range of skills and competencies. With the diversity of manikins, the nursing students are exposed into realistic complex clinical scenarios where they enhance their clinical skills, critical thinking and decision-making abilities in a safe and controlled environment. Several future trends and challenges are expected to alter the development and usage of manikins in nursing education with the integration of embedded sensors, wireless connectivity, virtual and augmented reality. Ongoing research interdisciplinary collaborations and adherence to ethical principles considerations are necessary to enhance the effectiveness and realism of manikin-based simulations and to ensure that manikin-based education remains aligned with evolving educational needs and professional standards*.

Keywords*– *Manikin, Nursing education, High fidelity, Low fidelity

I. INTRODUCTION

It is said that, long time ago nursing education relied heavily on theoretical teaching, live demonstrations, and hands-on experience with real patients. The introduction of manikins revolutionized nursing education(NE) by providing a controlled and repeatable environment for students to practice a wide range of clinical skills without putting real patients at risk. Manikins are anatomically accurate simulators that replicate human physiology and provide a realistic representation of patients in various clinical scenarios (Shinnick, Woo and Mentes, 2011). These patient simulators allow the nursing students to engage in hands-on learning that closely mimic real-world scenarios, promoting critical thinking, decision-making, and teamwork skills.

The objectives of this review article are to explore the role of manikins for nursing education and training, examining their effectiveness, advantages, and limitations. Additionally, we will delve into the different types of manikins utilized in nursing and highlight their applications in skill acquisition, clinical simulations, and patient assessment.

To provide a comprehensive overview, this review article will be structured as follows: First, we will delve into the historical development of manikins, tracing from their origins to modern advancements in the clinical setup.

Next, the categorization of manikins used in nursing education will be discussed along with their applications.

Furthermore, we will explore the design considerations and features of modern manikins.

To assess the effectiveness of manikins in nursing education, we will examine the evaluation and validation methods employed in research studies.

In addition, we will discuss emerging trends and future directions in manikin technology.

We will also address the challenges and ethical considerations associated with manikin use in nursing education (Adamson, Kardong-Edgren and Willhaus, 2013).

II. HISTORICAL DEVELOPMENT

The historical development of manikins in nursing education is a testament to the evolution of simulation-based training (Nehring and Lashley, 2009). Over the years, manikins have undergone significant advancements, transforming from basic models to sophisticated simulators (low fidelity to high fidelity) that closely resemble human anatomy and physiology (Nehring and Lashley, 2009).

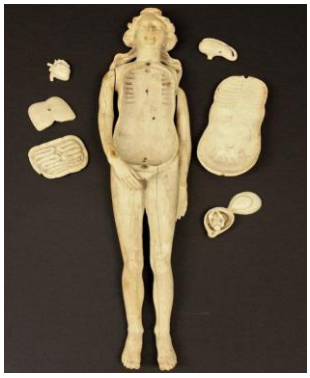

Figure 1: Manikins in first stages

The origins of manikins can be traced back to the early 18th century when anatomical models were first introduced which were made by primarily from wax or papier-mâché (Narang *et al.*, 2021), provided a static representation of human anatomy for teaching purposes (Narang *et al.*, 2021). However, they lacked the dynamic features necessary for simulating clinical scenarios.

In the mid-20th century, the development of more advanced manikins marked a significant milestone in nursing education (Nehring and Lashley, 2009). The introduction of rudimentary mechanical simulators enabled learners to practice basic skills, such as bandaging or intramuscular injections, on realistic models (Nehring and Lashley, 2009). These early manikins had limited functionality but laid the foundation for future advancements in the field.

As technology progressed, manikins became more sophisticated, incorporating realistic physiological responses. High-fidelity manikins, equipped with interactive features, emerged as powerful tools for simulating complex patient scenarios. These simulators could mimic vital signs, respiratory patterns, and even respond to interventions and medications (Choi, Lee and Gwon, 2021).

In recent years, the integration of computer technology and multimedia capabilities has further enhanced the realism of manikins. Virtual patient simulators, operated by computer software, provide an immersive learning environment that closely replicates the clinical setup (Danforth *et al.*, 2009). These simulators offer the clinical practitioners opportunity to practice critical thinking and decision-making in a safe and controlled environment.

Additionally, the advent of wireless technology and connectivity has revolutionized manikin-based education. Remote control and monitoring systems allow instructors to manipulate manikin responses and collect data during simulations, fostering a more dynamic and interactive learning experience (Livne, 2019).

The development of manikins has also been driven by research and collaboration between educators, healthcare professionals, and manufacturers. Research studies have explored the effectiveness of manikins in nursing education, examining their impact on learner outcomes, patient safety, and skill acquisition (Amado *et al.*, 2012). These studies have contributed to evidence-based practices in the integration of manikins into nursing curricula.

The integration of manikins in nursing education has not been without challenges. Manikins can be costly to acquire and maintain, requiring ongoing investment in equipment, software, and training. Furthermore, ensuring the fidelity and accuracy of manikins remains a continuous endeavor, as the complexity of clinical scenarios and patient needs continues to evolve (Fritz, Gray and Flanagan, 2008).

Looking ahead, the future of manikins in nursing education holds great promise. Advancements in technology, such as virtual reality and augmented reality, are poised to further enhance the realism and interactivity of manikin-based simulations. These technologies can provide learners with immersive, three-dimensional environments, allowing them to engage in realistic clinical scenarios and enhance their clinical decision-making skills (Fritz, Gray and Flanagan, 2008).

III. MANIKIN TYPES AND APPLICATIONS

Categorization of Manikins in nursing education is based on specific learning objectives and complexity of clinical scenarios. These types of manikins offer diverse applications, allowing the nursing students to develop a wide range of skills and competencies. In this section, we will explore the types of manikins commonly utilized in nursing education and their specific applications.

A. Basic or low-fidelity manikins

Basic or low-fidelity manikins are the most fundamental type of simulators used in nursing education. These manikins are typically made of plastic and have limited anatomical features. They are primarily used for teaching and practicing basic skills, such as taking vital signs, performing wound care, or administering injections (Nehring and Lashley, 2009). Basic manikins are cost-effective and provide beginners with an opportunity to familiarize themselves with basic clinical procedures in a controlled environment before moving on to more critical scenarios.

B. Mid-Fidelity Manikins

Mid-fidelity manikins represent a step up from basic manikins in terms of their anatomical detail and functionality. These simulators often feature interchangeable parts or modules that allow for the practice of more advanced skills. They can simulate palpable pulses, lung sounds, and may have more realistic airway passages for performing procedures like endotracheal intubation or nasogastric tube insertion (Nehring and Lashley, 2009). Mid-fidelity manikins are suitable for intermediate-level clinical practitioners who need to refine their skills and gain confidence in performing a wider range of procedures.

C. High-fidelity manikins

High-fidelity manikins are advanced simulators that closely mimic the physiological responses and anatomical features of real patients. These sophisticated simulators are equipped with built-in computer systems and sensors which enable them to construct a wide range of clinical scenarios. High-fidelity manikins can display realistic vital parameters, produce heart and lung sounds, and even respond to interventions and medications. They are often used for complex simulations, such as managing cardiac arrest, responding to emergencies, or conducting comprehensive patient assessments (Fritz, Gray and Flanagan, 2008). HF manikins provide learners with immersive experiences that closely resemble real clinical situations, fostering critical thinking and decision-making skills.

D. Specialized manikins

In addition to aforementioned manikins, there are specialized manikins designed for specific clinical scenarios such as for neonates, gynecology (Maenhout *et al.*, 2021). These manikins are tailored to replicate particular patient populations or specific healthcare settings. These manikins are designed for obstetric simulations such as delivering a baby or managing obstetric emergencies (Maenhout *et al.*, 2021). In addition, pediatric manikins are designed to develop specialized skills in caring for children. These specialized manikins provide targeted training experiences

that align with specific nursing specialties or patient populations.

E. Virtual patient simulators

Virtual patient simulators are a relatively new and rapidly evolving form of manikin-based education. These simulators utilize computer technology and virtual reality to create immersive, interactive learning environments. Virtual patient simulators can replicate realistic clinical scenarios, providing learners with the opportunity to practice clinical decision-making, critical thinking, and communication skills. These simulators often incorporate 3D graphics, interactive patient histories, and dynamic patient responses to interventions (King *et al.*, 2018). Virtual patient simulators offer the advantage of flexibility, as they can be accessed remotely and provide a standardized learning experience for students regardless of their location.

Each type of manikin has its own strengths and limitations, and the selection of the appropriate manikin depends on the desired learning objectives and the specific skills and competencies that need to be developed. It is essential for educators to carefully consider the educational goals and curricular requirements when deciding which type of manikin to incorporate into nursing education programs.

IV. DESIGN AND FEATURES

The design and features of manikins in NE play a crucial role in provide realistic and effective simulation experiences for clinical practitioners (CP). Manikins are meticulously designed to mimic the anatomical structure and physiological responses of humans, enabling nursing students to practice clinical scenarios. In this section, we will explore the key design elements and features of manikins that contribute to their effectiveness in NE.

A. *Anatomical accuracy*

One of the fundamental aspects of manikin design is anatomical accuracy. Manikins are crafted to closely resemble the human body, including skeletal structures, internal organs, and external features. The accurate representation of anatomy allows CPs to develop a comprehensive understanding of the spatial relationships between body systems and practice procedures that require precise anatomical positioning (Blackburn *et al.*, 2021). The level of anatomical detail varies depending on the type of manikin, with high-fidelity simulators providing a more intricate representation of human anatomy. Simulating anesthetic process is shown in Figure 2.

Figure 2: Advanced manikins at UC help military & civilians

B. Realistic Physiology and Functionality

To provide an authentic learning experience, manikins incorporate realistic physiology and functionality. This includes simulating vital positioning such as heart rate, blood pressure, respiratory rate, and body temperature. High-fidelity manikins are equipped with sensors which display the measurements of vital parameters, allowing learners to practice assessment skills while interpreting the physiological data (Blackburn *et al.*, 2021). Manikins can mimic physiological responses to interventions and medications, creating a dynamic and interactive simulation environment that reflects real clinical scenarios (Croxon and Maginnis, 2009)

C. Modularity and Interchangeable Parts

Many manikins are featured with modularity and interchangeable parts which allows for versatility in simulating a wide range of clinical scenarios. These design elements enable the educators to adapt the manikins to specific learning objectives by customizing with interchangeable limbs or anatomical modules to simulate different patient conditions or injuries. Therefore, the learners can practice a variety of skills and scenarios using a single simulator (Fritz, Gray and Flanagan, 2008).

D. Simulated Clinical Features

Manikins often incorporate simulated clinical features to enhance realism during simulations. For instance, the high-fidelity simulators may produce realistic heart and lung sounds, simulated bleeding, sweating, or tears to mimic specific patient conditions or physiological responses which allow the students to practice auscultation and identify abnormal findings closely to real clinical settings (Pritchard *et al.*, 2016).

E. Wireless Connectivity and Remote Control

Recent advancements have introduced wireless connectivity and remote-control capabilities into the manikin. Thereby, the instructors can monitor and control the manikin responses remotely during simulations while providing real-time feedback and adjust the scenario for specific outcomes (King *et al.*, 2018). Additionally, patient monitors and infusion pumps can be integrated using the wireless connectivity to enhance the learning experience.

F. Data Collection and Performance Metrics

Manikins often incorporates data collection capabilities to provide objective feedback on learner performance. Sensors embedded within the manikin have the capability to acquire various data of vital signs, timestamps, accuracy of interventions and effectiveness of procedures. These parameters will be used as metrics to assess the students' competency, progress and identify lagging areas for improvement (Smith and Hamilton, 2015).

G. Ease of Maintenance and Durability

Manikins are designed to withstand the rigors of frequent use and manipulation. They are constructed using durable materials that can withstand repeated procedures and handling. Furthermore, manikins are designed for ease of maintenance, allowing for regular cleaning, disinfection, and replacement of worn-out parts. This ensures that the

manikins remain in optimal condition for prolonged use, providing a reliable and consistent training resource for nursing education programs.

The design and features of manikins continue to evolve with technological advances and educational needs. Manufacturers and educators collaboratively develop innovative solutions to enhance the effectiveness and realism of manikin-based simulations. Ultimately nursing students can be prepared for the complexities and challenges encounter in clinical practice.

V. EVALUATION AND VALIDATION

Evaluation and validation are essential for a manikin to assess its effectiveness and reliability. Performing these procedures will ensure that the manikins are delivering accurate functionalities to mimic real-life clinical scenarios. In this section, we will discuss the importance of evaluation and validation along with the common procedures employed in assessing the quality and efficacy of manikins.

A. Evaluation of Fidelity

Fidelity refers to the accuracy of the manikin to replicate real patient conditions in terms of anatomical and physiological responses related to clinical scenarios. Expert reviews (Clinicians and educators), checklists and comparison studies are being used to evaluate fidelity of the manikins by assessing the resemblance to real patients and objective measures (Schiavenato, 2009). Thereby, the manufacturers will receive feedback on improvement of the manikin to enhance the educational value.

B. Validation of Functionality

Validation involves assessing the functionality and performance of manikins to ensure the accuracy of stimulating physiological responses and appropriate counter interventions.

Validation process is involved with collecting data on manikin's performance and comparing it with expected outcomes to established clinical guidelines and expert consensus (Shin, Park and Kim, 2015).

Validation process verifies that the manikins are capable of providing reliable and consistent feedback to learners during simulations which increase their confidence levels.

C. *Educational Outcomes Assessment*

Assessing the educational outcomes of manikin-based education is essential to determine its effectiveness in improving student learning and clinical competency. This evaluation involves measuring the impact of manikin-based training on knowledge acquisition, skill development, critical thinking, and clinical decision-making. Methods for assessing educational outcomes include pre and post-training assessments, clinical performance evaluations, surveys and peer interviews to gather their perceptions of the educational experience (Yuan *et al.*, 2012). By examining educational outcomes, educators can identify the strengths and limitations of teaching procedures to revise curriculum and instructional strategies.

D. User Satisfaction and Feedback

The user satisfaction and feedback are collected from nursing students, educators, and clinical experts. User satisfaction surveys, focus groups, and interviews can capture feedback on the manikins' realism, functionality and relevance to clinical practice. It Helps manufacturers to refine their designs and educators to tailor their instructional methods for a better learning experience (Yuan *et al.*, 2012).

E. Continued Improvement and Research

Manikins are required to be continuously assessed, refined and validated to align with best practices and evidence-based education. Therefore, collaboration among manufacturers, educators and researchers with progressive research and development are crucial for advancing the manikin-based education and ensuring its effectiveness in preparing nursing students for real-world clinical practice.

VI. FUTURE TRENDS AND CHALLENGES

Technological advancements and educational evolutions are expected to reshape the development and use of manikins in nursing education. In this section, we will discuss some of the future trends and challenges engaged with the manikin development.

A. Advancements in Technology

One of the significant future trends in manikin development is to incorporate more sophisticated features and capabilities which may improve the realism in terms of anatomical accuracy, physiological responses, and interactive functionalities.

Enhanced sensors, wireless connectivity and integration with virtual reality or augmented reality platforms are potential technological advancements that can further enhance the effectiveness and realism of manikin-based simulations (Smith and Hamilton, 2015).

B. Interdisciplinary Collaboration

Interdisciplinary collaborations with engineers, computer scientists, and industrial experts in simulation technology can foster innovation and create realistic and effective manikins. By leveraging the expertise of different disciplines, manikins can be designed to address the specific needs and to overcome the challenges of nursing education. Thereby, improved patient simulation experiences and better integration of manikin-based training can be achieved in healthcare education (Cant and Cooper, 2010).

C. Standardization and Best Practices

Standardization of manikin-based education and the establishment of best practices are critical for ensuring consistent and high-quality nursing education experiences. The development of standardized guidelines, protocols and assessment tools for manikin-based simulations can help the educators. This ensures to implement effective curricula, facilities for research and development and reliable training for nursing students. Standardization efforts should address issues of fidelity, functionality, and validity of manikins to align with established educational and clinical standards (Sando *et al.*, 2013).

D. Integration of Artificial Intelligence (AI)

The integration of artificial intelligence (AI) into manikins holds significant potential in the future of nursing education. AI algorithms can enhance the realism and responsiveness

of manikins by enabling them to adapt their behavior based on learner's actions and decisions. AI-powered manikins can provide personalized feedback, dynamically adjust simulation scenarios, and simulate complex patient conditions and responses. This integration can promote critical thinking, decision-making, and problem-solving skills among nursing students to prepare for dynamic and ever-evolving healthcare environment (Choi, Lee and Gwon, 2021).

E. Addressing Cost and Accessibility

While manikins offer numerous benefits in nursing education, cost and accessibility remain significant challenges. High-fidelity manikins can be expensive, limited access to certain institutes. Future trends should be focused on developing more affordable and accessible alternatives such as mid-fidelity or virtual simulators to provide better learning experience. Additionally, the establishment of partnerships among the educational institutions, healthcare organizations, and manufacturers would be helpful to overcome the financial barriers of affording high-end manikins to while ensuring broader access to simulation-based training (Ziv *et al.*, 2003).

F. Ethical Considerations and Simulation Realism

Ethical aspects should be considered as manikins become more advanced and realistic. The educators and institutions need to ensure that the use of manikins in simulations, maintains the highest standards of professionalism, respect for patient dignity, and privacy. Furthermore, discussions around simulation realism and the potential psychological impact on learners should be ongoing, with appropriate support systems in place to address any emotional or ethical concerns that may arise during the training (Ziv *et al.*, 2003).

VII. DISCUSSION

The prices of high-fidelity manikins can vary significantly based on the manufacturer, model, features, and included accessories. Prices can also change over time due to advancements in technology and changes in the market. Therefore, as it was mentioned earlier, the financial barrier is there for the developing countries as well as several institutions and programs when it comes to accessing the High-fidelity or Specialized manikins. According to the reports only few countries such as United States, United Kingdom, Canada, Australia, European Union, Japan, Middle East and Singapore, use high-fidelity manikins in order to enhance their nursing education. While poor nations can use some strategies like acquiring donations and grants, collaborative partnerships, technology sharing and open source, fundraising and awareness campaigns and local manufacturing. There is a possibility that upgrading those Low-fidelity manikins to High-fidelity or Specialized manikins as to the requirement of the end user might be useful to overcome this barrier.

VIII. CONCLUSION

This review, has explored various aspects of manikins including the historical development, types, applications, design features, evaluation, validation future trends and challenges.

Manikins are extensively used in nursing education to enhance clinical skills, critical thinking, and decision-making abilities. The diverse types of manikins such as task trainers, full-body simulators, and virtual simulators cater to different educational needs and clinical scenarios.

The design features of manikins continue to advance with manufacturers integrating technologies like sensors, wireless connectivity, virtual and augmented reality to enhance realism and interactivity. Evaluation and validation are critical for manikins to ensure the fidelity, functionality, and educational outcomes. Assessing the realism and effectiveness of manikins helpful for manufacturers to refine their designs, improve the quality of simulation-based education and educators to align with best practices.

Several Future trends and challenges such as advancements in technology, interdisciplinary collaborations, standardization efforts, integration of artificial intelligence, addressing cost and accessibility, and ethical considerations have been focused for the betterment of nursing education. These trends will contribute to the develop more realistic and effective manikins to prepare the nursing students for complex real-world clinical practices.

Manikins play a vital role in nursing education, offering a safe and controlled environment for students to practice and enhance their clinical skills. By providing realistic patient simulations, manikins bridge the gap between theory and practice. Ongoing research, interdisciplinary collaborations and ethical considerations are necessary to ensure that manikin-based education remains aligned with evolving educational needs and professional standards.

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